Mobile Augmented Reality Elements for Museum Hearing Impaired Visitors' Engagement

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***Abstract*— There is an increase attention on the provision of the ideal learning environment for museum visitors. This has made researchers to employ the concept of engagement in designing Mobile Augmented Reality application in order to attract museum visitors' interest and ensure a more effective learning environment. However, most of the Mobile Augmented Reality applications for museum visitors are largely tailored to normal hearing visitors while the hearing-impaired visitors are not supported. This makes hearing-impaired visitors to go through unpalatable experiences and eventually dissatisfy with their visit to the museum. This experience is making learning impossible for hearing-impaired visitors at the museum sites. Therefore, this study explored engagement Mobile Augmented Reality elements that are needed for the design of an efficient museum Mobile Augmented Reality application for hearing impaired visitors'. The study employed both systematic literature review and expert opinion methods. The findings revealed that there are eleven major elements of engagement Mobile Augmented Reality needed for the design of an efficient museum Mobile Augmented Reality app for hearing impaired visitors'. These eleven elements include Aesthetics, Curiosity, Usability, Interaction, Motivation, Satisfaction, Self-Efficacy, Perceived Control, Enjoyment, Focused Attention and Interest. This paper argues that for an efficient and engaged Mobile Augmented Reality app for the hearing-impaired community most especially hearing-impaired visitors to museum sites these eleven elements are critical. This finding will help Mobile Augmented Reality designers and developers on how to design an efficient and engaged Mobile Augmented Reality app for the hearing-impaired community at large and museum hearing-impaired visitors' specifically.**

***Index Terms*— Augmented Reality; Mobile Augmented Reality; Engagement App; Museum App; Hearing Impaired Application**

I. INTRODUCTION

Augmented reality (AR) involves the introduction of virtual objects into the real environment in order to obtain an augmented environment. This augmented environment is the direct superimposition of physical objects and computer-reproduced objects. The knowledge of AR is influencing human-computer interaction greatly with the today's proliferation of Mobile Augmented Reality applications (MAR apps) and the provision of social support within many domains ranging from healthcare to tourism. MAR apps benefits include mobility, handle, wearability, environment-awareness, multi-modal, flexible usage, visual alerts and reminders which have being social interaction positively.

Despite the facts that MAR apps have enormous benefits to human beings both socially and industrially, however, there are still few technical limitations of these applications such as outdoor and portability use, depth perception, tracking and calibration, user experience, overload, and over-reliance [1]. Out of these limitations, many studies have focused on users' experience because it is believed to promote MAR social acceptance. This has made researchers such as [2], [3], [4], [5] and [6] to investigate on ways to increase the users' engagement and learning in MAR. In these studies engagements depicts the act of raising users' attractiveness and interest in a pleasing manner in order to get their attention to performing activities at the museums whereas learning refers to informal learning can be obtained in museum environment.

Nevertheless, there is still lack of study that explores MAR users' engagement and learning criteria among the Hearing-Impaired (HI) people, especially among museum HI visitors and tourists. It is unfortunate that the HI tourists are having huge difficulties not only with accessibility issues within museum but also with engagement experience [7]. Likewise, it is unfortunate that little is known about how people with hearing losses can have an engaging inform learning experience within museums. This is because most of the technological solutions and devices provided in the most museums are not suitable and appropriate to enhance HI visitors' and tourists' engagement experience.

The HI people account for over 5% of the world's populace which is about 360 million people [8]. Out of this populace, 124 million people are affected with moderate to severe HI while 108 million from 124 million live in low and middle-income countries like Eastern Asia, South Asia, Asia-Pacific and sub-Saharan Africa. From this populace, 328 million are adults where around 33% of these are over 65 years old [9]. HI children are approximately 32 million worldwide while 65 million individuals were affected by hearing loss from childhood.

Despite the huge numbers of HI people, there is little attention on their need most especially on suitable MAR app during their visit to museum and cultural sites. Whereas, if there is suitable MAR app during their visit to museum and cultural sites it will motivate them to patronage the sites and there will be profit increment for both the MAR app designers and the museum management. Hence, this study aims to explore engagement MAR elements that are needed for the design of an efficient museum MAR app for hearing impaired visitors'

II. Review Of Literature

MAR is a form of AR which allows users to interact with the augmented environment without being distracted. It allows MAR user to be in focus, movable and freely engages with the augmented environment to achieve the desired objective. This same scenario is intended for museum MAR because museum visitors need to be focus and movable in order to interact with the augmented environment. As pointed out by [10], there are four major classes of museum mobile technology namely mobile phone navigational system, mobile guide apps, web-based apps and web-to-mobile apps. The first class is the mobile phone navigational systems which make use of maps to provide guidance for museum tourists' using interactive platforms like tablet and phone [11].

Similarly, mobile guide apps generally make use of mobile communicating devices to provide museum tourists with information [12], [13]. On the other hand, web-to-mobile apps utilize the website to provide museum tourists' information using a combination of website and mobile online applications [14]. Whereas, web-based apps are similar to the web-to-mobile system but the apps only utilize website application browser only and displays the information on a mobile platform (like phones and tablets) [15]. Out of the four aforementioned museum mobile technologies, mobile guide apps technology is the most used especially in AR environment. This class of technology is commonly used because of it interactive and movable nature which makes it easier for museum tourists' to be more focused. This is why most museum MAR apps are based on this class.

Additionally, many previous studies in the vast literature addressed issues of formal and informal learning however, little attention is given to of users' engagement which might be one of the rationales for failures of existing museum MAR apps [16]. The issue of users' engagement is a very important concept in museum visitation because engagement enhances user entertainment, learning, and acceptability which have a direct influence on tourists' experiences [17]. Additionally, none of these studies specifically focus on the HI tourists while most of the studies in the vast literature majorly were targeted toward hearing people. Likewise, the most used class is the mobile guide app because it provides details information and learning platform to users. Hence, this present study will explore mobile guide apps MAR in order to ensure tourist engagement experience at the site.

In order to better understand tourist engagement experience, there is need to understand the concept of user experience (UX) which is defined as the engagement of user perception and reality with a given app which depends on their assessment of the app quality, service, and usage [18]. It refers to user deep comprehension and feeling of the app which is rooted in if the app meets their need, value, abilities, and expectation which is illustrated in Figure 1.

This is what informs users' interaction with the app and from their conclusion about the app. User engagement experience demands if they are satisfied with not alone the app design but also its efficiency. Based on UX concept, many studies have equally explored the issue of museum user experience (MUX) because it has to do with museum visitors' personalize experience. This experience depicts the feeling and deep comprehension of users during their visit to the museum sites. Their feeling and experience on the museum is based on many factors which have been explored by many studies.

An Example of studies that have explored MUX is [19] which investigated the concept of user experience on the MAR hand puppet historical museum in Taiwan. She introduced iBeacon sensor AR device to improve the museum users' experience within the hand puppetry museum. The conclusion of the study shows that user experience is enhanced with the use of AR and technology generally. The study pinpoints the need to gamifying museum environment and allows the museum to interact with users in an interesting manner. This same approach was implemented by [20] on Finnish Luostarinmäki Handicrafts Museum. Their findings likewise supported [19] conclusion that gamification of museum MAR will make the app more interactive and improve MUX. Similarly, [21] study focused on improving Gansu Provincial Museum in China which was faced with low patronage and visitation by tourists. Their main focus was on how to use digital technology (like AR, MAR, interactive games) to engage users' experience during their visit to the museum. In their conclusion, they were able to implement museum MAR and museum interactive games which positively enhanced the users' experience and increase patronage of visits to the museum site. This same concept was implemented by [22] in order to improve MUX in Inner Mongolia Museum in China. They developed a mobile digital museum which received overwhelming responses from many users because of its positive engagement and interactive factors.

Another major work that contributed to MUX was by [23] which focused on improving UX of visitors to the Palazzo Madama-Museo Civico d'Arte Antica in Torino Italy. They explored on making Museum mobile applications to positively enhance visitors' experience within the museum. Thus, the study results revealed that easy to use, the interaction platform, information dissimilation and informative graphical interface are vital to MUX. Also, [24] made a similar conclusion in their study on MUX in Gwacheon national science museum, a national museum in Gwacheon South Korea. They concluded that museum interior design and interactive factors are vital in emphasizing interaction museum design installation for MUX.

Apart from these studies, other notable studies that have contributed to MUX include [25], [26], and [27]. For example [25] used Radio Frequency Identification (RFID) technology to positively enhance MUX beyond the museum walls. Their study was carried out at the Exploratorium museum (which is a hands-on science museum) in San Francisco. In their findings, it was pinpointed that flexibility, interactive and convenience are one of the factors to enhance MUX. Another study that had a similar finding and was equally carried out at the Exploratorium museum was done by [27]. His study explored the rationale to improve MUX using nomadic web content design. It was concluded that sense of isolation, integrating real-place and virtual contexts, explanations, exhibit history, social identity and enjoyable factors are vital in MUX. Also, [26] developed The Electronic Guidebook which is a mobile web resource developed to improve MUX in Exploratorium museum of San Francisco. It was identified that users' engagement and convenience are two important factors to ensure positive MUX. in Exploratorium museum of San

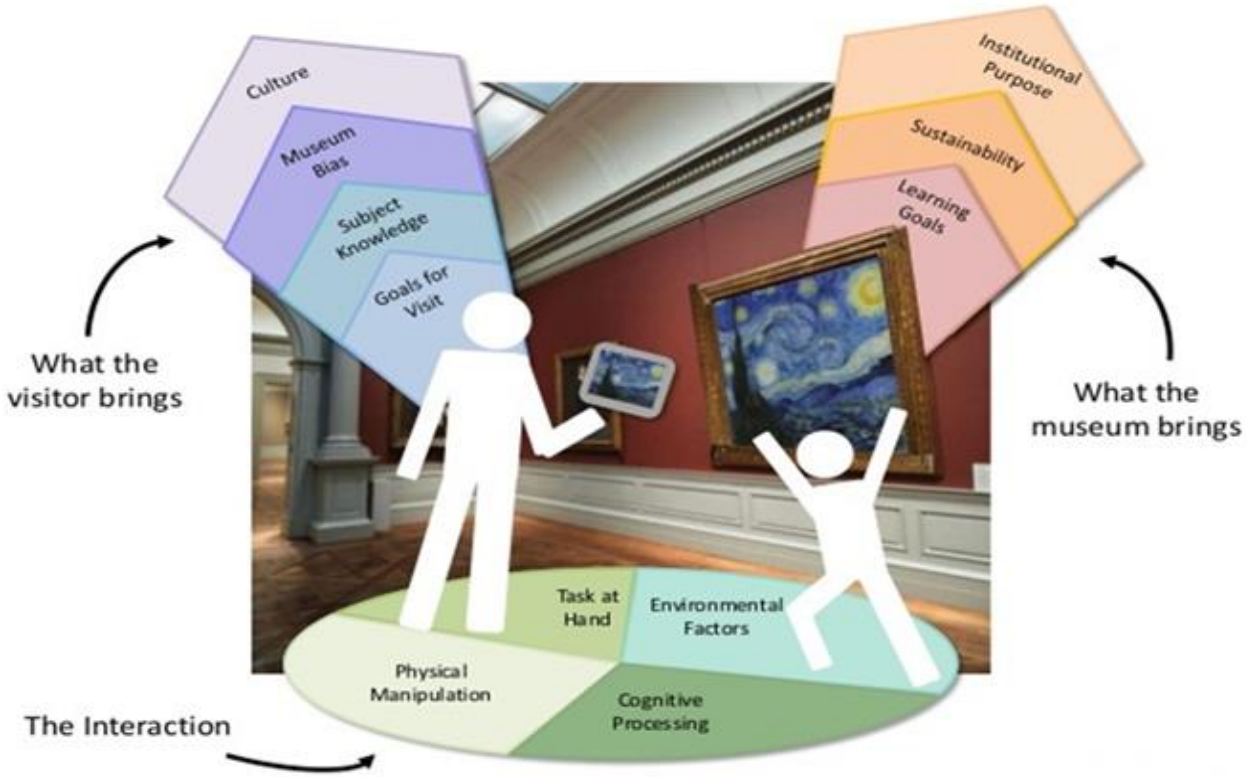

Figure 1: MUX Interactions Platform

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Furthermore, it is important to mention that the museum has its selling points which are the major purposes of the museum. The point that these two major purposes (users and museum) is known as the interaction platform. This platform is very important because it determines the outcome of MUX either positive or negative. This is why many studies emphasis on the need to reduce distractions, psychological reactance, dissatisfaction and users' information overload during their visit to the museums in order to ensure positive outcomes. Likewise, there is need to ensure that the platform for MUX is engaging in order to ensure positive outcomes. These are the rationales for this and the consideration of UX in this present study. The understanding of user experience has aided the concepts of interactive, enjoyable, learning and engagement of mobile apps.

Out of the four aforementioned concepts (namely interactive, enjoyable, informal learning and engagement), the implementation of the concept of engagement in MAR apps has been considered the most difficult in the light of novelty, users felt involvement and endurability. This is because most mobile apps are found not be endurable which usually will not make users continue with their usage [28]. The concept of engagement is widely used in person-centered practice research such as behavioral change intervention and user-centered studies. According to [29], the concept of engagement involves the decision by a user to undertake tasks (as given by the mobile application) related to his interest and competence, practice it continuously by interacting immensely and deeply in order to continue the task with persistence and commitment because of the value attributed to the task.

[30] explained engagement in term of multimedia perspective as a system that enables users' curiosity, attention focus, and intrinsic interest. In addition, [31] pointed out that engagement is the attributes that depict the quality of user's value, experience and continuity with a mobile application. Similarly, many scholars have explained mobile app engagement in terms of users' attitude and behavior [32], [33], user stickiness [34], long-term retention [35], user's impact [36], users' measure of comprehension on an app [37].

In order to fully comprehend the rationale for this issue, there is a need to explore the various dimensions of the concept of engagement in MAR apps. As established in the previous section that engagement involves users' interest and competence. The concepts of interest and competence are deeply rooted in users' feelings and sense-making on the mobile app. According to [38], the concept of users' engagement with the mobile app is more than user involvement interaction. Users' involvement depicts the interaction that is without feeling or compliance which will not result in engagement. The study by [39] shed better light on the issue of engagement of mobile app when discussing the three major dimensions of engagement namely behavioral, emotional and cognitive.

Behavioral engagement is when users show optimism, curiosity, passion and attention towards a mobile app which usually increase motivation to learn. Emotional engagement is when users show affective tendencies such as a sense of belonging and fun with the mobile app. Cognitive engagement is when users show critical thinking level by challenging themselves in the interaction with the mobile app.

Based on the on-going review, engagement of audience is a key issue on the mobile application. As mentioned by [40] that researchers work hard and meticulously to design, develop and market mobile app, however, many of these products do not last in the market. It was reported that most previously developed applications failed to engage user which usually leads to failure in users' retention and usage of these applications. It further concluded that user engagement experience is vital in order for users to use the

application over and over again. Likewise, a survey has shown that only around 24% of mobile applications are used by users once before discarding them [28] whereas these apps were intended for long-term users' engagement by developers.

For instance in healthcare domain, MAR engagement is required for effective and efficient patients' treatment and monitoring [36]. MAR has make patients to have active role in their treatment decision making whereas they can collaborate, share information and receive treatment at their convenience. Thus, MAR provide patients with easier access to lab results, medical statement and other documentation. Likewise, MAR has been used successful to enhance community development. Many apps such as by [41] and [42]) are developed to actively engage community members in order to create awareness and participation. Similar, MAR developments have been done in human computing domain such as [43] and [44] where users' engagement is explored. It can be seen that MAR apps have been implemented in various domains such as health interventions, education, human computing technology, behavioral changes and user experiences medium whereas the healthcare domain was found to be the most frequently applied domain in the vast literature [45]. Whereas, it was discovered that majority of studies focuses on medical, decision support, communication, teaching and learning apps but there is less focus on engagement in the museum MAR apps. Nevertheless, notable studies on museum MAR apps include [46], [47], [48], [49], [50] and [51] as summarized in Table 1.

Most of these mentioned studies address issues of formal and informal learning however, little attention is given to users' engagement which might be one of the rationales for failures of existing museum MAR apps [16]. Moreover, there are limited studies on MAR HI tourists and most importantly it can be seen that none of the studies in the vast literature explored on museum MAR app for HI visitors' which can be used for their informal learning and enjoyable activities at the museum sites

III. Methodology

The main aim of this study is to explore the engagement MAR elements that are needed for the design of an efficient museum MAR app for hearing impaired visitors. The study employed the combination of both systematic literature review and expert opinion. This approach was considered suitable based on the objective of the study and as implemented in a similar study by [52]. The systematic literature review was used to identify the elements whereas the expert opinion was used to validate (check the consistency of these elements to the real scenario) the identified elements. There were five phases involved in the study methodology as summarized in Figure 2.

IV. Findings

Based on the study objective, the first phase of this study is to conduct a systematic review from the related database on MAR which includes IEEE, SpringerLink, World Scientific and ScienceDirect. The key words used for this review includes mobile augmented reality engagement. These key words were searched combinatorial and interchangeably in order to obtain more specific and refine outcomes. Based on these searches, a total of 116 related studies were selected and reviewed critically where 39 elements were identified. The 39 identified elements were further examined by investigating these that are relevant to HI people where these elements were examined in the light of HI literature. Only 20 out of the 39 elements were found to be related to the HI people. Then, the 20 elements were presented for expert opinion where the experts were made up of academicians, HI medical personnel, museum management and MAR designer and a total of 11 elements were selected. These 11 selected elements are considered as the major engagement MAR elements that are needed for the design of an efficient museum MAR app for hearing impaired visitors which are summarized in Table 2.

V. Discussion

The presented eleven elements are identified to trigger engagement in MAR apps for HI visitors at the museum and gallery sites. These elements are further discussed as follows:

A. *Aesthetics***:** This is one of the elements identified and it is the element of mixing the nature of beauty, art, and taste and with the creation and appreciation of HI MAR [57]. This element injects the theory of beauty into MAR, so that mobile users can appreciate the expression and representation of the message that the MAR app is conveying as expressed in [31].

B. *Curiosity:* This is the element that describes quality about inquisitive thinking which will push users to internal exploration and investigation. This concept promotes informal learning whereas users learn by investigating and exploration. The concept has been implemented in studies such as [58], [59], [60], [61] where it is discovered that apps that increase user curiosity can successfully engage the users in learning environment.

C. *Usability:* This is the element of flexibility, ease of use and learnability of MAR. As mentioned by [62], ease of use of a system is one of the measuring tools for evaluating MAR apps. Similar concept has been implemented in studies like [63], [60], [31], [64] and [65] where it is maintained that usability promotes users engagement and satisfaction with the MAR.

D. *Interaction:* This element depicts the way and manner that users and app connects. This is important because the platform and nature of the app communication will affect users' engagement with the app [58]. Thus, ability to connect between users and application is critical to engagement [65]

Table 1
Summary of Selected Museum MAR

No	Model	Description	Limitation	Reference
1	Museum Tourist Experience	Visitor experience in the mixed environment by combining both VR & AR	Focus only on economic factors	[46]
2	Service oriented MAR architecture for multiple applications	Support for content acquisition and utilization of the third party digital media contents on a real scene.	A web-based application that lacks interactive media.	[47]
3	Enjoyable Informal Learning MAR	Enjoyable Informal Learning Mobile augmented reality	Focus on enjoyable and learning without providing assistive support to any target group	[48]
4	Mobile Augmented Reality Tour (MART)	The app provides context-awareness and the information provision about the artefact in the museum.	Information awareness without interactive media and assistive support	[49]
5	TechCoolTour	Augmented 3D reconstruction, 3D virtual character, video, 360 degrees' panorama with heritage site	Non interactive and engagement	[50]
6	Framework and Data Flow of AR-based on-site Tour Guide:	Based on a framework that contains data flow of application which consists of two agents, the contextual management agent, and map management agent.	The framework only provides tour guide flow and lack interactive media	[51]
7	Architecture System of Sutoon-Hoo Mobile Augmented Reality	Uses architecture system and divided into two namely initialization, and object categorization by involving components, such as object assignment, inventory, and museum database	The content structure was not well defined and mainly performs as a tour guide.	[53]
8	Intelligent Tourism and Cultural Information through Ubiquitous Service (iTACITUS)	Superimposed environment annotated landscape, and spatial acoustic overlays to present the AR information on a smartphone platform	Interactive but not assistive support	[54]
9	MobiAR	MobiAR is an Android service platform for tourist information based on AR, which allows users to browse information and multimedia content about a city through their own mobile devices.	Is a static app with no interaction platform	[55]
10	Mobile Guides Museum	AR-enabled mobile multimedia museum guide designed and implemented for the Museum of Fine Arts in Rennes, France.	No interactive platform	[56]

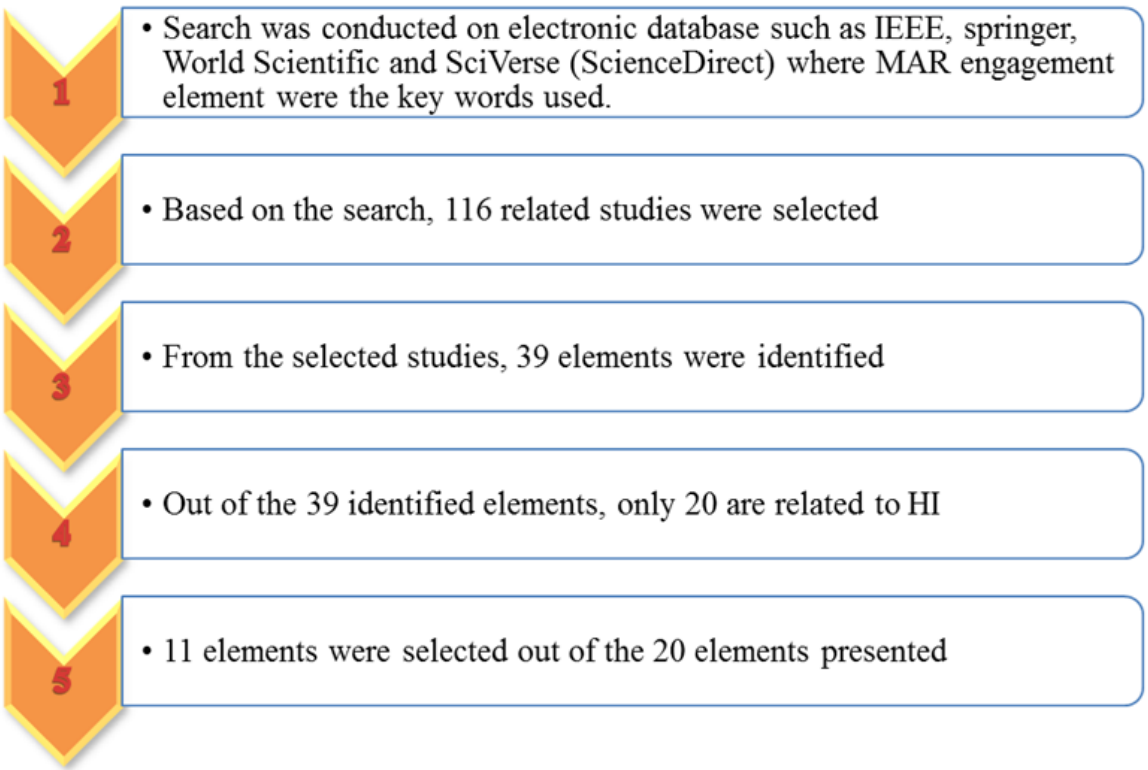

Figure 2: Study Methodology

E. *Self-efficacy:* This element defines confident in users' belief in their ability to succeed in specific situations or accomplish a task. Based on [69] and [70] studies, any apps that enhance users' self-efficacy will also engage them.

F. *Perceived Control:* This is the belief that users feel that they are in control of the event or situation within an app. Is a state that users have the understanding that they determine the internal situation and event within an app. This state becomes more intense when users belief they have more control and influence on the app environment and/or bring about desired outcomes. This element has been used in studies such as [59] and [63] where it is noted that users' perceived control on an app promotes their engagement.

G. *Enjoyment:* Is an element which implies the feeling of being benefiting to the conveying message of app. This element involves users experiencing fun, joy, satisfaction, peace and fulfilment based on their interaction with the apps [71].

H. *Focused Attention:* This is the element that portraits attraction of awareness in order to make a communicated message more interesting and fun to users [72]. Many studies such as [31], [72], [4] and [70] implemented this element in their studies and concluded that apps which are able to gain attention of users will successfully engage users.

I. *Interest:* The element of interest is the gaining of users' awareness and concern in order to get them involves and participates in predefined action or behavior. Many studies such as [67], [58] and [4] have argued that users' engagement is succeed when they are interested in the app message.

Table 2
Summary of the Identified Eleven Elements

No	Element	Description	Reference
1	Aesthetics	Visual beauty or the study of natural and pleasing (or aesthetic) computer-based environments	[31]
2	Curiosity	This is when the human mind thirst for knowledge by investigates an environment, object or situation in search of the knowledge.	[59]
3	Usability	This is the measurement of the suitability and ease of use app functionality as perceived by the users'. It is the users' emotional experienced when using an app and it defines users' efforts, feeling and control on the app.	[73], [31]
4	Interaction	This a form of social relation and connection between users' and an app	[74]
5	Motivation	This is a drive toward involvement in order to achieve (a fun and enjoy) a target (learning or playing)	[75]
6	Satisfaction	This is the act of being contend and fond with an app	[66]
7	Self-Efficacy	Self-efficacy is one's belief in one's ability to perform a desired outcome while Computer self-efficacy is the belief in one's ability to perform a desired outcome using a computer.	[77]
8	Perceived Control	Act of dominating, commanding and regulating others, an activity, or a system.	[59]
9	Enjoyment	The user experiencing fun, joy, satisfaction, peace and fulfillment with the usage of apps.	[78], [79]
10	Focused Attention	The ability to involved and absorbed on a specific task by losing track of time without being distracted	[31]
11	Interest	This when an object or system is attract attention, provoke thought, intrigue and fascinate a user.	[80]

VI. CONCLUSION

This study has been able to depict vital elements that are needed for the design of museum MAR apps for engaging HI visitors. These eleven elements include Aesthetics, Curiosity, Usability, Interaction, Motivation, Satisfaction, Self-Efficacy, Perceived Control, Enjoyment, Focused Attention and Interest. This paper argues that for an efficient and engaged MAR app for the HI community most especially HI visitors to museum sites, these eleven elements are critical. It is crucial for museum MAR designers to consider these elements in their designs in order to positively engage the HI for both inform learning and amusement at the museum sites. Likewise, these elements will ensure that museum MAR app transcends beyond the use of displaying texts and videos at the museum and gallery sites whereas it will ensure that proper information is communicated and understood for the target users. Hence, this study has presented eleven major elements of engagement of MAR needed for the design of an efficient museum MAR app for the hearing impaired visitors. These elements will be reviewed by experts consisting of those from the MAR, Museum and HI. Nevertheless, there are still some future works to be done on the issues of museum MAR apps in engaging HI visitors such as developing a conceptual model and guidelines for the design of the museum MAR app. This will help MAR designers and developers on how to design an efficient and engaged MAR app for the HI community at large and museum HI visitors specifically.

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